Comparison of growth, development, survivorship and food utilization of two color varieties of *Tenebrio molitor* (Coleoptera: Tenebrionidae)

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Abstract: *Tenebrio molitor* L. is an important resource insect. Based on the cuticular color of 60-day-old larvae, the yellow- and black-color varieties of *T. molitor* were obtained through natural selection of 12 consecutive generations. In order to provide further scientific data for cultivating new good breeds, the growth, development, survivorship and food utilization of the two color varieties of *T. molitor* were studied at first. The hatch rate and pupation rate of the two color varieties showed no significant difference and were about 83% and 97% for both, respectively. But the emergence rate of the yellow-color variety (female, 95%; male, 91%) was strikingly higher than that of the black one (female, 82%; male, 83%). The developmental duration of eggs and pupae of both varieties was about 7 d and 10 d, respectively, showing no significant difference, too. But the larvae of the black-color variety developed faster and more orderly than the yellow ones. Larvae of the black-color variety went through 12 - 15 instars in all, while the yellow-color ones went through 12 - 17 instars. Most of them went through 14 instars, for both the yellow- and black-color varieties. In the yellow-color variety, there were 27% larvae with 14 instars, while 53% in the black-color variety. If taking the larvae with 14 instars into consideration, the whole developmental duration of the yellow- and black-color varieties from egg to adult was about 171 d and 151 d, respectively. The yellow-color larvae had an average food utilization efficiency significantly higher than that of the black ones. The average approximate digestibility, efficiency of converting digested food and efficiency of converting ingested food of larvae of the yellow-color variety were 66.5%, 50.6% and 33.6%, respectively, while those of larvae of the black-color variety were 62.1%, 46.8% and 29.1%, respectively. There were no significant differences in the growth and survival rates between varieties at the same day age. In conclusion, the black-color variety of *T. molitor* develops faster and more orderly than the yellow-color variety, while the yellow-color variety has an average food utilization efficiency significantly higher than that of the black-color one. The results provide some useful reference for breeding new good varieties of *T. molitor*.

Key words: *Tenebrio molitor*; color variety; growth rate; survival rate; developmental duration; food utilization efficiency

1 INTRODUCTION

Tenebrio molitor L. (Coleoptera: Tenebrionidae) is one of resource insects which contains rich fat and protein, many kinds of amino acids, unsaturated fatty acids and minerals (Ye *et al*., 1997; Huang *et al*., 2006, 2007). There are large quantities of food sources for the mealworm beetle. It is easy to culture and characterized by low feeding cost since it has short generation cycle and strong living ability. Nowadays it has been widely applied into agriculture, animal husbandry, food, medical care and so on, showing bright market future. In the animal husbandry, *T. molitor* is a kind of protein feed or bait for livestock, poultry and other special economic animals. In the biological control of the agricultural pests, the larvae and pupae of *T. molitor*

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are used as substitute hosts for mass rearing of several kinds of natural enemy (Zanuncio *et al*., 2000; Tian and Xu, 2003; Huang *et al*., 2005a; He *et al*., 2006; Wu *et al*., 2008). In addition, *T. molitor* is an important native material for health food, health care medicine and natural antibacterial peptide or protein (Zhao *et al*., 2004; Huang *et al*., 2005b; Wu *et al*., 2007; Zhang *et al*., 2009; Liu *et al*., 2009; Wang *et al*., 2009a, 2009b). Recently, the rearing scale of mealworm beetle has been increased gradually and a new industry chain has emerged in provinces such as Shandong and Hebei, the core of which is raising and comprehensive utilization of *T. molitor*. However, the quality of the mealworm beetle variety is degenerating, which has become the bottleneck restricting the further sustainable and healthy development of the industry. So it is urgent to cultivate new breeds of *T. molitor*. Up to now, very limited data on new breeds of *T. molitor* cultivation is available.

Cuticular color in *T. molitor* is a quantitative trait, varying from tan to black (Armitage and Siva-Jothy, 2005). Cuticular color is a continuous, melanin-dependent and heritable trait in *T. molitor* (Thompson *et al*., 2002; Rolff and Siva-Jothy, 2003), but the specific inheritance of the cuticular color is still waiting for further research. The degree of cuticular melanization was a strong indicator of resistance in *T. molitor*, with darker beetles being more resistant to the entomopathogenic fungus *Metarhizium anisopliae* than lighter ones regardless of rearing density (Barnes and Siva-Jothy, 2000). Haemocyte density and preimmune challenge activity of phenoloxidase (PO) (two important immune parameters related to resistance) were significantly higher in selection lines of black beetles compared to tan lines (Armitage and Siva-Jothy, 2005). Thus it can be seen that breeding the mealworm beetle varieties with the representative cuticular color has the theoretical and practical significance for cultivating new good breeds of *T. molitor*.

Based on the cuticular color of 60-day-old larvae, the yellow- and black-color varieties of *T. molitor*, with good genetic stability, were obtained through natural selection of 12 consecutive generations for more than 4 years by the Forest Protection Laboratory of Sichuan Agricultural University. In order to provide more scientific data for further cultivating new good breeds, the growth, development, survivorship and food utilization of the two color varieties of *T. molitor* were studied.

2 MATERIALS AND METHODS

2.1 Experimental insects

The yellow- and black-color varieties of *T. molitor* were obtained through the natural selection of 12 consecutive generations for more than 4 years by the Forest Protection Laboratory of Sichuan Agricultural University. They were fed on bran (as the principal feed) and carrot (as the subsidiary feed) and cultured at 25℃ – 30℃, 50% – 70% RH and in the natural diffused light.

2.2 Estimation of hatchability

One hundred one-day-old eggs of each color variety were sampled randomly and put into the plate (D = 11 cm) to cultivate with 5 replicates. The amount of larvae hatched was recorded on time once a day until the 10th day. The hatchability was calculated according to the following formula. Hatch rate = total number of the larvae hatched / number of the tested eggs × 100%.

2.3 Assessment of the larval survival rate, growth rate and food utilization efficiency

One hundred newly hatched larvae of each color variety were sampled randomly and weighed. Then they were put and reared in the plastic pot (30 cm × 20 cm × 10 cm), where enough weighed fresh bran was provided until the tested larvae began to pupate. The tested larvae were examined every other day meanwhile the dead larvae were removed and weighed once they were found. The frass was sifted out every 10 days and the larvae were segregated simultaneously from the remaining food with writing brush. Then the larvae, frass and remaining food were respectively weighed and enough bran was added again. All the supplied and remaining bran and the evacuated frass were dried to constant weight in the 80℃ cabinet drier. Larvae of the two color varieties at the same day age sampled from control groups were weighed and dried to constant weight, too. The food intake was determined by dry weight of the supplied and remaining food. The dry weight increase of larvae was determined by ratio of the dry weight to fresh weight. Approximate digestibility (AD), efficiency of converting digested food (ECD) and efficiency of converting ingested food (ECI) at different day-old larvae were calculated according to the tested data. The growth rate was defined as dry weight increase of 100 larvae per day. Survival rate = [number of tested larvae – number of dead larvae]/ number of tested larvae × 100%; AD = [dry food intake (mg) – dry frass evacuated (mg)]/dry food intake (mg) × 100%; ECD = dry

weight increase (mg)/[dry food intake (mg) − dry frass evacuated (mg)] × 100%; ECI = dry weight increase (mg)/dry food intake (mg) × 100%. Each color variety of *T. molitor* was repeated 5 times.

2.4 Estimation of pupation rate

One hundred mature larvae (over the 11th instar) of each variety were sampled randomly and 5 replicates for each variety. They were put and bred in the plastic pot (30 cm × 20 cm × 10 cm) where some fresh bran was supplied. The amount of pupae emerged was recorded once a day for 2 months. The pupation rate was calculated according to the following formula. Pupation rate = number of the pupae pupated/number of the tested larvae × 100%.

2.5 Estimation of emergence rate

One hundred healthy one-day-old male and female pupae of each variety were sampled randomly, 5 replicates for each variety. They were uniformly put and cultured in the insect specimen box (28 cm × 18 cm × 3.5 cm) under the surface of which covered with a thin layer of fresh bran. The amount of the male and female adults emerged was recorded once a day for 10 days. The emergence rate was calculated according to the following formula. Emergence rate = number of the male (or female) adults emerged / number of the tested male (or female) pupae × 100%.

2.6 Assessment of developmental duration

A one-day-old egg of each variety was sampled randomly and put into the plate (D = 11 cm) to rear, which was examined once a day to see whether it hatched. A little fresh bran was added as food once the larva hatched. The food intake and molting of the larvae were examined on time once a day; while quantum sufficient bran or feeder green was added in time until the adult emerged. The incubation, pupation and emergence time, molting times and every molting time of the larvae were recorded, respectively. Developmental duration of the eggs, larvae and pupae and the whole developmental duration were calculated eventually. Each color variety of *T. molitor* was repeated 15 times. One mealworm beetle was tested each time.

2.7 Data statistics and analysis

All test data were analyzed by the one-way ANOVA of SPSS13.0 and test of the significance of difference was done by Duncan's multiple comparison.

3 RESULTS

3.1 Hatch, pupation and emergence rates

Hatch and pupation rate of the yellow- and black-color variety of *T. molitor* showed no significant difference, while emergence rate of the yellow-color variety was strikingly higher than that of the black one, for both male and female (Table 1).

Table 1 Hatch, pupation and emergence rates of two color varieties of *Tenebrio molitor*

Color variety	Hatch rate (%)	Pupation rate (%)	Emergence rate (%)	
			Female	Male
Yellow	83.4 ± 1.8	96.8 ± 0.9	94.8 ± 0.8	91.2 ± 0.7
Black	83.0 ± 0.8	97.0 ± 0.7	81.8 ± 0.9	82.8 ± 1.0
F value	0.04	0.03	17.28	6.80
P value	0.84	0.86	0.00	0.03

The data in the table were given as mean ± *SD* from 5 replicates. The same for the following tables.

3.2 Survival rate, growth rate and food utilization efficiency of larvae

There were no significant differences in the growth and survival rates between larvae of the two varieties at the same day age (Tables 2, 3). But in either of two color varieties, the growth and survival rates of the different day-old larvae showed marked difference. The survival rate of the larvae under 30 days was the highest, and that of the larvae over 120 days was the lowest (Table 2). The larvae under 30 days grew slowest, while the 60 − 120 day-old larvae grew fastest. But the growth rate of the larvae over 120 days decreased sharply (Table 3).

Table 2 Survival rate of different day-old larvae of two color varieties of *Tenebrio molitor*

Color variety	Survival rate (%)					*F* value	*P* value
	30 d	60 d	90 d	120 d	150 d		
Yellow	97.6 ± 0.5 a	96.4 ± 0.7 ab	93.6 ± 0.5 bc	93.0 ± 0.5 c	92.0 ± 0.7 c	15.82	0.00
Black	97.4 ± 0.7 a	96.2 ± 0.9 ab	94.4 ± 1.4 bc	93.2 ± 1.6 c	91.6 ± 1.3 c	3.74	0.02
F value	0.08	0.03	0.28	0.01	0.08		
P value	0.79	0.86	0.61	0.91	0.79		

The data within a row followed by different letters were significantly different at $P < 0.05$ by Duncan's multiple range test. The same for the following Table 3 and Tables 7 − 11.

Food intake and frass evacuated by different day-old larvae of two color varieties of *T. molitor* were given in Table 4 and Table 5, respectively, and the weight increase of them was given in Table 6.

During the whole experiment period, the approximate digestibility (AD) of larvae of the yellow-color variety was significantly higher than that of the black ones at the same day age (Table 7). The efficiency of converting ingested food (ECI) of the yellow larvae between 90 – 150 days was remarkably higher than that of the black ones at the same day age (Table 9). All the average AD, ECD and ECI of the yellow larvae were significantly higher than those of the black ones (Tables 7 – 9). The results showed that the yellow-color variety had an average food utilization efficiency significantly higher than that of the black-color one.

In either of the two color varieties, the AD, ECD and ECI of different day-old larvae showed significant difference. AD of the larvae under 60 days, ECD and ECI of the larvae under 30 days were the lowest. AD, ECD and ECI of the larvae between 60 – 120 days were relatively higher, while all the AD, ECD and ECI of the larvae over 120 days decreased quickly (Tables 7 – 9).

Table 3　Growth rate of different day-old larvae of two color varieties of *Tenebrio molitor*

Color variety	Growth rate (dry weight increase /100 larvae · d, mg)					Average growth rate (dry weight increase /100 larvae · d, mg) (0 – 150 d)	*F* value	*P* value
	0 – 30 d	30 – 60 d	60 – 90 d	90 – 120 d	120 – 150 d			
Yellow	2.6 ± 0.2 e	12.6 ± 0.9 d	86.4 ± 2.0 a	83.8 ± 2.5 a	29.5 ± 1.5 c	38.7 ± 1.2 b	209.00	0.00
Black	2.9 ± 0.2 e	10.4 ± 0.3 d	82.4 ± 1.2 a	85.3 ± 2.9 a	30.4 ± 1.6 c	38.0 ± 0.8 b	317.04	0.00
F value	1.76	5.05	0.97	0.16	0.03	0.25		
P value	0.22	0.06	0.35	0.70	0.87	0.63		

Table 4　Food intake by different day-old larvae of two color varieties of *Tenebrio molitor*

Color variety	Food intake (dry weight, mg)						*F* value	*P* value
	0 – 30 d	30 – 60 d	60 – 90 d	90 – 120 d	120 – 150 d	0 – 150 d		
Yellow	28.5 ± 3.1	129.3 ± 5.3	665.9 ± 7.2	572.7 ± 1.4	308.9 ± 3.4	2 077.3 ± 6.5	310.61	0.00
Black	36.8 ± 1.8	115.6 ± 3.9	679.8 ± 1.7	649.3 ± 2.0	358.8 ± 3.4	2 355.3 ± 5.7	855.47	0.00
F value	5.47	4.34	0.04	9.71	1.09	10.30		
P value	0.05	0.07	0.86	0.01	0.33	0.01		

Table 5　Frass evacuated by different day-old larvae of two color varieties of *Tenebrio molitor*

Color variety	Frass evacuated (dry weight, mg)						*F* value	*P* value
	0 – 30 d	30 – 60 d	60 – 90 d	90 – 120 d	120 – 150 d	0 – 150 d		
Yellow	10.7 ± 1.2	47.9 ± 2.1	208.0 ± 2.4	139.6 ± 5.8	101.9 ± 11.3	696.3 ± 24.5	290.04	0.00
Black	15.5 ± 0.8	47.8 ± 1.6	241.1 ± 1.4	193.2 ± .8.4	134.7 ± 13.9	893.1 ± 25.0	664.74	0.00
F value	11.96	0.00	1.74	27.56	3.33	32.12		
P value	0.01	0.97	0.22	0.00	0.11	0.00		

Table 6　Weight increase of different day-old larvae of two color varieties of *Tenebrio molitor*

Color variety	Weight increase (dry weight, mg)						*F* value	*P* value
	0 – 30 d	30 – 60 d	60 – 90 d	90 – 120 d	120 – 150 d	0 – 150 d		
Yellow	7.6 ± 0.1	37.0 ± 2.7	236.3 ± 9.5	211.6 ± 6.1	98.8 ± 11.5	697.7 ± 21.4	531.81	0.00
Black	8.8 ± 0.5	30.3 ± 0.8	226.9 ± 4.1	217.2 ± 6.2	101.4 ± 10.3	684.0 ± 14.4	1 002.84	0.00
F value	1.96	5.75	0.83	0.41	0.03	0.28		
P value	0.20	0.04	0.39	0.54	0.87	0.61		

Table 7 Approximate digestibility (AD) of different day-old larvae of two color varieties of *Tenebrio molitor*

Color variety	AD (%)					Average AD (%) 0 – 150 d	*F* value	*P* value
	0 – 30 d	30 – 60 d	60 – 90 d	90 – 120 d	120 – 150 d			
Yellow	62.5 ± 0.4 f	63.0 ± 0.1 f	68.9 ± 0.4 c	75.7 ± 0.5 a	67.0 ± 0.1 d	66.5 ± 0.1 d	219.00	0.00
Black	58.0 ± 0.2 g	58.7 ± 0.3 g	64.6 ± 0.3 e	70.3 ± 0.6 b	62.6 ± 0.6 f	62.1 ± 0.2 f	131.74	0.00
F value	141.49	192.97	62.37	47.94	60.91	253.11		
P value	0.00	0.00	0.00	0.00	0.00	0.00		

Table 8 Efficiency of converting digested food (ECD) of different day-old larvae of two color varieties of *Tenebrio molitor*

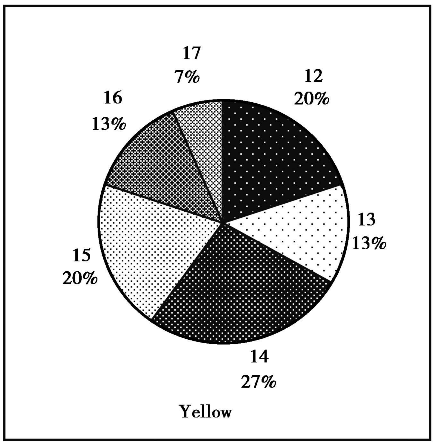
Color variety	ECD (%)					Average ECD (%) 0 – 150 d	*F* value	*P* value
	0 – 30 d	30 – 60 d	60 – 90 d	90 – 120 d	120 – 150 d			
Yellow	43.3 ± 1.7 de	45.2 ± 1.6 cde	53.1 ± 3.8 a	48.9 ± 0.5 abc	47.6 ± 1.4 bcd	50.6 ± 1.0 ab	3.35	0.02
Black	41.4 ± 2.1 e	44.8 ± 0.7 cde	51.8 ± 0.5 ab	47.7 ± 0.9 bcd	45.1 ± 0.8 cde	46.8 ± 0.2 bcd	10.41	0.00
F value	0.47	0.06	0.12	1.27	2.47	15.06		
P value	0.51	0.81	0.74	0.29	0.16	0.01		

Table 9 Efficiency of converting ingested food (ECI) of different day-old larvae of two color varieties of *Tenebrio molitor*

Color variety	ECI (%)					Average ECI (%) 0 – 150 d	*F* value	*P* value
	0 – 30 d	30 – 60 d	60 – 90 d	90 – 120 d	120 – 150 d			
Yellow	27.1 ± 1.2 ef	28.5 ± 1.0 e	36.6 ± 2.7 ab	36.9 ± 0.4 a	31.9 ± 0.9 cd	33.6 ± 0.7 bc	9.02	0.00
Black	24.0 ± 1.2 f	26.3 ± 0.4 ef	33.4 ± 0.4 bc	33.5 ± 0.5 bc	28.2 ± 0.4 e	29.1 ± 0.2 de	40.54	0.00
F value	3.34	4.33	1.33	31.43	14.58	40.29		
P value	0.11	0.07	0.28	0.00	0.01	0.00		

3.3 Instars of larvae

Larvae of the black-color variety went through 12 – 15 instars in all, while larvae of the yellow-color variety went through 12 – 17 instars. Most of larvae of both varieties went through 14 instars. There were 27% larvae with 14 instars in the yellow-color variety while 53% in the black-color variety (Fig. 1). The result showed that larvae of the black-color variety grew more orderly than the yellow ones.



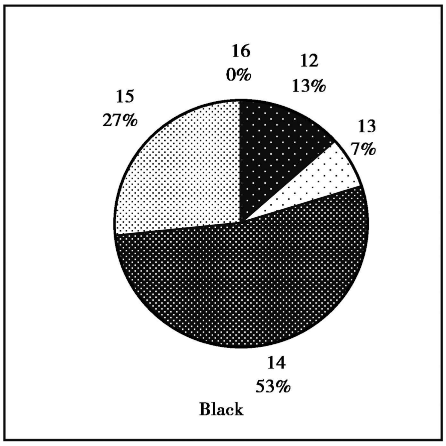


Fig. 1 Instars of larvae of two color varieties of *Tenebrio molitor*

3.4 Developmental duration

Developmental duration of the eggs and pupae of two color varieties showed no significant difference, while the larval duration of the black-color variety was shorter than that of the yellow one (Tables 10, 11). If taking the larvae with 14 instars into consideration, the whole developmental duration of the yellow- and black-color varieties from egg to adult was about 171 d and 151 d, respectively (Table 11). The above results showed that the black-color variety developed faster than the yellow one.

Table 10 Developmental duration of different instars of larvae of two color varieties of *Tenebrio molitor*

Color variety	Instars (d)																	*F* value	*P* value
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th		
Yellow	2.7 ± 0.1 a	8.7 ± 0.4 bc	8.3 ± 0.6 bc	7.8 ± 0.3 bc	6.8 ± 0.2 b	7.3 ± 0.3 bc	8.3 ± 0.7 bc	7.6 ± 0.4 bc	7.3 ± 0.3 bc	8.4 ± 0.6 bc	13.0 ± 1.5 d	16.4 ± 0.9 e	20.8 ± 1.6 gh	22.2 ± 3.4 gh	19.8 ± 2.5 fg	24.2 ± 2.7	27.5	31.17	0.00
Black	2.9 ± 0.1 a	7.8 ± 0.4 bc	7.0 ± 0.3 bc	7.1 ± 0.2 bc	7.0 ± 0.3 bc	6.4 ± 0.2 b	7.5 ± 0.2 bc	7.5 ± 0.2 bc	7.0 ± 0.3 bc	7.9 ± 0.7 bc	9.7 ± 0.6 c	16.0 ± 0.5 e	18.1 ± 1.2 ef	22.6 ± 0.8 h	25.3 ± 4.0 i			97.48	0.00
F value	1.05	2.56	3.54	3.01	0.27	8.09	1.20	0.06	0.74	0.37	4.21	0.17	1.80	0.02	1.50				
P value	0.32	0.12	0.07	0.09	0.61	0.01	0.28	0.81	0.40	0.55	0.05	0.68	0.19	0.89	0.26				

The data in the table were given as mean ± *SD* from replicates. The same for Table 11. The test of the significance of difference was done between the developmental duration of 1st – 15th larval instars of the two color varieties. But the test did not include the developmental duration of the 16th and 17th instars because the 16th and 17th instars only appeared in the yellow-color variety.

Table 11 Duration of different developmental stages of two color varieties of *Tenebrio molitor*

Color variety	Egg developmental duration (d)	Larval developmental duration (d)				Pupal developmental duration (d)	Whole developmental duration from egg to adult (d)
		1 – 12 instars	1 – 13 instars	1 – 14 instars	1 – 15 instars		
Yellow	7.4 ±0.1 h	102.5 ±2.6 f	125.0 ±3.9 d	154.3 ±7.9 b	176.3 ±9.0 a	9.8 ±0.5 h	171.0 ±8.3 a
Black	7.4 ±0.0 h	93.6 ±1.4 g	111.6 ±1.9 e	134.1 ±3.2 c	157.6 ±6.0 b	9.7 ±0.2 h	151.2 ±3.0 b
F value	0.00	8.79	10.48	8.65	3.29	0.05	8.30
P value	1.00	0.01	0.00	0.02	0.13	0.83	0.02

Taking the larvae with 14 instars into consideration when determining the whole developmental duration.

4 DISCUSSION

Instars of the mealworm beetle larvae reported previously were very different because the molting times of the larvae was related to the environmental temperature and nutrition level, and even under the same conditions, the molting times of different individuals showed some difference (Peng and Huang, 1993; Liu *et al*., 2002). In this experiment, the larvae of the black-color variety went through 12 – 15 instars, while the yellow ones went through 12 – 17 instars. And most of larvae of the two color varieties went through 14 instars. If taking the larvae with 14 instars into consideration, the whole developmental duration of the yellow and black varieties from egg to adult was about 171 d and 151 d, respectively. Obviously, the black-color variety developed faster and more orderly than the yellow one. Growing fast and orderly would be helpful to rearing management.

On the other hand, the larvae of the yellow-color variety had an average food utilization efficiency significantly higher than that of the black ones. Larval stage is the main period for the mealworm beetle to ingest food and grow. High food utilization efficiency would be beneficial to reduce the food cost.

Finally, it is to be mentioned that the growth and survival rates of different day-old larvae showed significant difference in either of the two color varieties. During the whole larval period of the mealworm beetle, the 60 – 120 day-old larvae grew fastest, while the mortality of them was relatively higher, too. But the growth rate of the mature larvae over 120 days decreased quickly. So it is very important to take better care of the 60 – 120 day-old larvae in the culture. And in order to cut down the feeding cost, it would be best that the breeding time of the mealworm beetle larvae used for commodity was not beyond 120 days.

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两种色型黄粉虫的生长发育、存活与饲料利用效率比较研究

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摘要：黄粉虫 *Tenebrio molitor* L. 是一种重要的资源昆虫，根据60日龄幼虫的体壁颜色，通过连续12代的自然选育，获得了黄、黑2种色型黄粉虫。为进一步给黄粉虫优良品种培育提供科学的理论依据，本实验首先对选育出的2种色型黄粉虫的生长发育、存活及饲料利用效率进行了比较研究。结果表明：2种色型黄粉虫的孵化率和化蛹率均约为83%和97%，无显著差异；但黄色型成虫的羽化率(♀：95%，♂：91%)却明显高于黑色型成虫的羽化率(♀：82%，♂：83%)。2种色型黄粉虫的卵和蛹历期均约为7 d和10 d，亦无显著差异；但黑色型幼虫较黄色型幼虫发育更快、更整齐。黑色型幼虫共历经12~15龄，黄色型幼虫历经12~17龄，并且2种色型黄粉虫幼虫均以历经14龄居多，历经14龄的黄、黑2色型黄粉虫幼虫的比例分别为27%和53%。以14龄计，黄、黑2色型黄粉虫从卵至成虫的总历期分别为171 d和151 d。此外，黄色型幼虫对饲料的平均利用效率明显高于同日龄黑色型幼虫，黄色型幼虫的平均饲料消化率(AD)、转化率(ECD)和利用率(ECI)分别为66.5%，50.6%和33.6%，而黑色型幼虫的平均饲料消化率(AD)、转化率(ECD)和利用率(ECI)分别为62.1%，46.8%和29.1%；但2种色型黄粉虫同日龄幼虫的生长率和存活率差异不显著。综合上述结果可知，黑色型黄粉虫较黄色型黄粉虫发育更快、更整齐，而黄色型黄粉虫对饲料的平均利用效率明显高于黑色型黄粉虫。这为进一步培育黄粉虫优良品种提供了有益参考。

关键词：黄粉虫；色型；生长率；存活率；发育历期；饲料利用效率

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